

ENGLISH  
TRANSLATION  
OF INTERNATIONAL  
APPLICATION AS FILED

## DESCRIPTION

### ANGULAR VELOCITY MEASURING DEVICE

#### Technical Field

The present invention relates to an angular velocity measuring device suitably used for detecting an angular velocity, for example.

#### Background Art

Generally, an angular velocity measuring device in which an angular velocity detection element and a signal processing element are mounted is known (see Patent Document 1, for example). In this case, the angular velocity detection element is constituted by a vibrating body contained so as to be vibrated in first and second axial directions out of three axes at right angles to each other, driving means for making the vibrating body vibrate in the first axial direction by a drive signal, and displacement detecting means for detecting a displacement in the second axial direction of the vibrating body and outputting a detection signal when an angular velocity is applied around the third axis while the vibrating body is vibrated in the first axial direction. Furthermore, a drive wiring and a detection wiring connected to the driving means and the displacement detecting means of the angular velocity detection element, respectively, are contained in the substrate, and the angular

velocity detection element and the signal processing element are connected through the wirings.

Patent Document 1: Japanese Unexamined Patent Application  
Publication No. 10-300475

In the angular velocity measuring device according to such a related technology, when a drive signal is inputted from the signal processing element to the angular velocity detection element through a drive wiring, the driving means makes the vibrating body vibrate in the first axial direction on the basis of the drive signal. In this state, when an angular velocity is applied around the third axis, a Coriolis force operates to the vibrating body in the second axial direction. In this way, since the vibrating body is displaced in the second axial direction in accordance with the angular velocity, the displacement detecting means detects the amount of displacement of the vibrating body in the second axial direction as a change of electrostatic capacitance, etc., and outputs a detection signal in accordance with the angular velocity. Then, the signal processing element receives the detection signal from the displacement detecting means through the detection wiring and calculates the angular velocity by performing various calculation processes concerning the detection signal.

Now, since the detection wiring is of a high impedance in the order of megohms ( $\times 10^6 \Omega$ ), in the above-described related

technology, crosstalk occurs through a coupling capacitance between the drive wiring and the detection wiring and there are cases in which drive signals mix into a detection signal. At this time, since both the drive wiring and the detection wiring according to the related technology are contained on the surface of the substrate, sufficient shielding cannot be performed around the detection wiring of a high impedance and the coupling capacitance between the drive wiring and the detection wiring cannot be reduced. Accordingly, in the related technology, the drive wirings and the detection wirings two each are contained in accordance with two drive signals and detection signals having different signs, and the balance of coupling capacitance between the drive wirings and the detection wirings two each is adjusted to cancel crosstalk.

However, in such a construction according to the related technology, since the coupling capacitance between the drive wiring and the detection wiring has a large absolute value, a small amount of coupling capacitance (a few fF, for example) is left because of variations of the wirings, etc.). At this time, when a weak angular velocity is detected, for example, since the detection signal also becomes very weak, even if the crosstalk due to a very tiny coupling capacitance makes a very large output at rest generated in comparison with the detection sensitivity. As a result, there is a problem in that the deviation of output

at rest and offset temperature drift characteristics are greatly affected.

Furthermore, in the related technology, in order to reduce the coupling capacitance, the drive wirings are formed so as to be symmetrical to the two detection wirings. However, in this case, the lead-out of the wiring is limited, and the mounting surface including the wiring, etc., is increased and there is a problem in that the freedom of disposition of the angular velocity detection element, the signal processing element, etc., is lowered.

Moreover, in the related technology, since the lead-out of the wiring is limited and simultaneously the freedom of disposition of the elements is low, the angular velocity detection element is difficult to be flip-chip mounted on the substrate. That is, in order to flip-chip mount the angular velocity detection element on the substrate, it is required to dispose the electrodes (wirings) on the substrate side at high density in accordance with the electrodes on the element side and to make the wirings symmetrical in order to reduce the coupling capacitance. In contrast with this, in the related technology, since the lead-out of the wirings, etc., are limited, the wirings which are at high density and being symmetrical cannot be realized. As a result, in the related technology, since an angular velocity detection element is mounted on the substrate by

using wire bonding, the common use in the mounting processing of parts is impossible and the productivity is lowered, and crosstalk mixes through the coupling capacitance between wires and there is a problem in that deviation of output at rest and offset temperature drift characteristics are worsened.

#### Disclosure of Invention

The present invention has been made in consideration of the above-described problems of the related technology, and it is an object of the present invention to provide an angular velocity measuring device in which detection wirings of a high impedance are effectively shielded, restrictions in the lead-out of wirings and the disposition of elements are removed, and the mounting area can be reduced.

1) In order to solve the above-described problems, the present invention is applied to an angular velocity measuring device comprising a substrate; an angular velocity detection element having a vibrating body contained in the substrate so as to be vibrated in the first and second axial directions out of three axial directions corresponding to three axes at right angles to each other, driving means for vibrating the vibrating body in the first axial direction using a drive signal, and displacement detecting means for detecting displacement in the second axial direction of the vibrating body and outputting a detection signal when an angular velocity is applied around the

third axis while the vibrating body is vibrated in the first axial direction; drive wiring contained in the substrate and connected to the driving means of the angular velocity detection element; detection wiring contained in the substrate and connected to the displacement detecting means of the angular velocity detecting means; and signal processing means contained in the substrate and connected to the drive wiring and the detection wiring.

Then, a structure adopted by the present invention is characterized in that the substrate is a multilayer substrate made up of a plurality of insulation layers; the detection wiring is disposed between two insulation layers inside the multilayer substrate; low-impedance wiring facing the detection wiring is contained at a position different from the detection wiring in the thickness direction of the multilayer substrate therein; in the angular velocity detection element, an element-side drive electrode connected to the driving means, an element-side detection electrode connected to the displacement detecting means, and an element-side low-impedance electrode positioned between the element-side drive electrode and the element-side detection electrode and for cutting off the coupling between the element-side drive electrode and the element-side detection electrode positioned on the mounting surface side to the multilayer substrate are contained; on the top surface of the multilayer

substrate, a substrate-side drive electrode connected to the drive wiring and facing the element-side drive electrode, a substrate-side detection electrode connected to the detection wiring and facing the element-side detection electrode, and a substrate-side low-impedance electrode positioned between the substrate-side drive electrode and the substrate-side detection electrode and for cutting off the coupling between the substrate-side drive electrode and the substrate-side detection electrode are contained; the angular velocity detection element is mounted on the top surface of the multilayer substrate by using metal bumps; the element-side drive electrode and the substrate-side drive electrode are connected by using metal bumps; the element-side detection electrode and the substrate-side detection electrode are connected by using metal bumps; the element-side low-impedance electrode and the substrate-side low-impedance electrode are connected at a low-impedance reference potential; and the element-side low-impedance electrode and the substrate-side low-impedance electrode are made to at least partially face each other.

When constructed in this way, since a detection wiring is contained inside a multilayer substrate and a low-impedance wiring facing the detection wiring at a position different from the detection wiring in the thickness direction is contained in the multilayer substrate, a high-impedance detection wiring can



be shielded by using the low-impedance wiring. Accordingly, it is able to prevent a drive signal from mixing into a detection signal between the drive wiring and the detection wiring and, as a result, it is able to prevent deviation of output at rest and improve offset temperature drift characteristics.

Furthermore, since a multilayer substrate is used as a substrate where an angular velocity detection element, etc., are mounted, in comparison with the case in which a single-layer substrate is used as in the related technology, the restriction of lead-out to the drive wiring, detection wiring, etc., can be removed and the degree of freedom of disposition of an element, etc., can be increased. As a result, the mounting area including the wiring, etc., is reduced and the device can be made smaller as a whole.

Moreover, since the wiring is freely led by busing a multilayer substrate, the electrodes for connecting an angular velocity detection element is disposed at high density on the surface of the multilayer substrate, and the drive wiring and the detection wiring can be disposed so as to be symmetrical, for example. Accordingly, the angular velocity detection element can be flip-chip mounted on the multilayer substrate and, in comparison with the case where wire-bonding mounting is performed, the productivity and detection sensitivity can be improved.

Furthermore, since an element-side low-impedance electrode

is contained between an element-side drive electrode and an element-side detection electrode on the mounting surface of an angular velocity detection element, the coupling between the element-side drive electrode and the element-side detection electrode can be cut off by the element-side low-noise electrode. Here, when the angular velocity detection element is flip-chip mounted on the multilayer substrate by using metal bumps, the element-side drive electrode and the substrate-side drive electrode are connected to each other so as to face each other and the element-side detection electrode and the substrate-side detection electrode are also connected to each other so as to face each other. Accordingly, since the element-side low-impedance electrode is disposed between the substrate-side drive electrode and the substrate-side detection electrode, the coupling between the substrate-side drive electrode and the substrate-side detection electrode is also cut off by the element-side low-impedance electrode. As a result, the occurrence of crosstalk between these electrodes is prevented and offset temperature drift characteristics can be improved.

On the other hand, since a substrate-side low-impedance electrode is contained between the substrate-side drive electrode and the substrate-side detection electrode on the top surface of the multilayer substrate, the coupling between the substrate-side drive electrode and the substrate-side detection electrode can be

cut off by the substrate-side low-impedance electrode. Here, when an angular velocity detection element is flip-chip mounted on the multilayer substrate by using metal bumps, the element-side drive electrode and the substrate-side drive electrode are connected to each other so as to face each other and the element-side detection electrode and the substrate-side detection electrode are also connected to each other so as to face each other. Accordingly, since the substrate-side low-impedance electrode is disposed between the element-side drive electrode and the element-side detection electrode, the coupling between the element-side drive electrode and the element-side detection electrode can be also cut off by the substrate-side low-impedance electrode. As a result, the occurrence of crosstalk between the electrodes is prevented and offset temperature drift characteristics can be improved.

Moreover, in the present invention, when an angular velocity detection element is flip-chip mounted on the multilayer substrate by using metal bumps, the element-side low-impedance electrode and the substrate-side low-impedance electrode at least partially face each other. At this time, the opposite portion where the element-side low-impedance electrode and the substrate-side low-impedance electrode face each other is positioned between the substrate-side drive electrode and the substrate-side detection electrode and also positioned between the element-side

drive electrode and the element-side detection electrode. Accordingly, by using the opposite portion of the two low-impedance electrodes, the coupling between the substrate-side drive electrode and the element-side detection electrode is cut off and the coupling between the element-side drive electrode and the substrate-side detection electrode can be also cut off. As a result, the occurrence of crosstalk between the electrode on the substrate side and the electrode on the element side is prevented and offset temperature drift characteristics can be improved.

2) Furthermore, another structure adopted by the present invention is characterized in that the substrate is a multilayer substrate made up of a plurality of insulation layers; the detection wiring is disposed between two insulation layers inside the multilayer substrate; low-impedance wiring facing the detection wiring is contained at a position different from the detection wiring in the thickness direction in the multilayer substrate; in the angular velocity detection element, an element-side drive electrode positioned to the mounting surface side to the multilayer substrate and connected to the driving means, an element-side detection electrode connected to the displacement detecting means, and an element-side low-impedance electrode enclosing the element-side drive electrode or the element-side detection electrode and for cutting off the coupling between the element-side drive electrode and the element-side detection

electrode are contained; on the top surface of the multilayer substrate, a substrate-side drive electrode connected to the drive wiring and facing the element-side drive electrode, a substrate-side detection electrode connected to the detection wiring and facing the element-side detection electrode, and a substrate-side low-impedance electrode enclosing the substrate-side drive electrode or the substrate-side detection electrode and for cutting off the coupling between the substrate-side drive electrode and the substrate-side detection electrode are contained; the angular velocity detection element is mounted on the top surface of the multilayer substrate by using metal bumps; the element-side drive electrode and the substrate-side drive electrode are connected by using metal bumps; the element-side detection electrode and the substrate-side detection electrode are connected by using metal bumps; the element-side low-impedance electrode and the substrate-side low-impedance electrode are connected at a low-impedance reference potential; and the element-side low-impedance electrode and the substrate-side low-impedance electrode are made to at least partially face each other between the element-side drive electrode and the element-side detection electrode.

When constituted in this way, a high-impedance detection wiring can be shielded by using a low-impedance wiring. Accordingly, it is able to prevent a drive signal from mixing

into a detection signal between the drive wiring and the detection wiring and, as a result, deviation output at rest is prevented and offset temperature drift characteristics can be improved.

Furthermore, since a multilayer substrate is used as a substrate where an angular velocity detection element, etc., are mounted, it is able to increase the degree of freedom of disposition of an element, etc. As a result, the mounting area including the wiring, etc., is reduced and the device can be made smaller as a whole.

Furthermore, since the wiring is freely set by using a multilayer substrate, the drive electrode and the detection electrode can be disposed at free positions on the surface of the multilayer substrate and the mounting surface of the angular velocity detection element. Accordingly, the angular velocity detection element is flip-chip mounted on the multilayer substrate and, in comparison with the case where wire bonding mounting is performed, the productivity and detection sensitivity can be improved.

Furthermore, since an element-side low-impedance electrode enclosing an element-side drive electrode or an element-side detection electrode is contained on the mounting surface of an angular velocity detection element, the coupling between the element-side drive electrode and the element-side detection

electrode can be cut off by the element-side low-impedance electrode. On the other hand, since an substrate-side low-impedance electrode enclosing an substrate-side drive electrode or an substrate-side detection electrode is contained on the surface of a multilayer substrate, the coupling between the substrate-side drive electrode and the substrate-side detection electrode can be cut off by the substrate-side low-impedance electrode.

Moreover, in the present invention, when an angular velocity detection element is flip-chip mounted on a multilayer substrate by using metal bumps, an element-side low-impedance electrode and a substrate-side low-impedance electrode at least partially face each other between the element-side drive electrode and the element-side detection electrode. At this time, the opposite portion where the element-side low-impedance electrode and the substrate-side low-impedance electrode face each other is positioned between the element-side drive electrode and the element-side detection electrode and also positioned the substrate-side drive electrode and the substrate-side detection electrode. Accordingly, by using the opposite portion of the two low-impedances, the coupling between the element-side detection electrode and the element-side detection electrode is cut off and the coupling between the element-side drive electrode and the substrate-side detection electrode can be also cut off. As a

result, the occurrence of crosstalk between the electrode on the substrate side and the electrode on the element side can be prevented and offset temperature drift characteristics can be improved.

3) In this case, in the present invention, the opposite portion, in which the element-side low-impedance electrode and the substrate-side low-impedance electrode face each other, may enclose the element-side detection electrode and the substrate-side detection electrode.

In this way, since the opposite portion of the two low-impedance electrodes enclose both detection electrodes on the element side and the substrate side, the coupling between the detection electrodes and the element-side drive electrode and substrate-side drive electrode can be surely cut off. As a result, the occurrence of crosstalk between the drive electrode and the detection electrode is prevented and offset temperature drift characteristics can be improved.

#### Brief Description of the Drawings

Fig. 1 is a perspective view showing an angular velocity measuring device according to a first embodiment of the present invention.

Fig. 2 is a block diagram showing an angular velocity detection element in Fig. 1.

Fig. 3 is an enlarged exploded perspective view showing the



angular velocity detection element and a multilayer substrate in Fig. 1.

Fig. 4 is a bottom view showing the angular velocity detection element in Fig. 3.

Fig. 5 is a top view showing the multilayer substrate in Fig. 3, in which a resist film is removed.

Fig. 6 is an illustration showing the portion in which a ground electrode of the angular velocity detection element and a ground electrode of the multilayer substrate of the first embodiment face each other.

Fig. 7 is a sectional view of the angular velocity measuring device taken on line VII - VII of Fig. 1.

Fig. 8 is a sectional view of the angular velocity measuring device taken on line VIII - VIII of Fig. 1.

Fig. 9 is an exploded perspective view showing the multilayer substrate in Fig. 1.

Fig. 10 is a front view showing an angular velocity measuring device according to a second embodiment.

Fig. 11 is an exploded perspective view showing an angular velocity detection element and a multilayer substrate according to a third embodiment.

Fig. 12 is a bottom view showing the angular velocity detection element in Fig. 11.

Fig. 13 is a top view showing the multilayer substrate in

Fig. 11 in which a resist film is removed.

Fig. 14 is an illustration showing the portion in which a ground electrode of the angular velocity detection element and a ground electrode of the multilayer substrate of the third embodiment face each other.

Fig. 15 is an exploded perspective view showing the multilayer substrate according to the third embodiment.

Fig. 16 is a bottom view showing an angular velocity detection element according to a first modified example.

Fig. 17 is an illustration showing the portion in which a ground electrode of the angular velocity detection element and a ground electrode of the multilayer substrate of the first modified example face each other.

Fig. 18 is a bottom view showing an angular velocity detection element according to a fourth embodiment.

Fig. 19 is a top view showing a multilayer substrate according to the fourth embodiment in which a resist film is removed.

Fig. 20 is an illustration showing the portion in which a ground electrode of the angular velocity detection element and a ground electrode of the multilayer substrate of the fourth embodiment face each other.

#### Reference Numerals

1 angular velocity detection element

2 element substrate  
3 and 4 vibrating bodies  
5A, 5B, 6A, and 6B drive portions (driving means)  
7A, 7B, 8A, and 8B detection portions (displacement  
detecting means)  
9 to 12, 71 to 74, and 121 to 124 element-side drive  
electrodes  
13, 14, 75, 76, 125, and 126 element-side detection  
electrodes  
15, 77, and 127 ground electrodes (element-side low-  
impedance electrodes)  
21, 81, and 128 multilayer substrates  
22 to 24, and 82 to 85 insulation layers  
29 to 32, 91 to 94, and 129 to 132 substrate-side drive  
electrodes  
33, 34, 95, 96, 133, and 134 substrate-side detection  
electrodes  
35, 97, 97', and 135 ground electrodes (substrate-side low-  
impedance electrodes)  
41, 42, 102, and 103 drive wirings  
43, 44, 105, and 106 detection wirings  
45, 50, 51, 107, 112, and 113 ground electrodes (low-  
impedance wirings)

Best Mode for Carrying Out the Invention

Hereinafter, an angular velocity measuring device according to a preferable embodiment of the present invention is described with reference to the accompanied drawings.

Here, Figs. 1 to 9 show a first embodiment. In the drawings, reference numeral 1 represents an angular velocity detection element made up of a vibration-type gyro element mounted on a multilayer substrate 21 to be described later. As shown in Fig. 2, the angular velocity detection element 1 is generally constituted by vibrating bodies 3 and 4 which can be displaced in first and second axial directions (X-axis direction and Y-axis direction) parallel to an element substrate out of three axes, drive portions 5A, 5B, 6A, and 6B as driving means for driving the vibrating bodies 3 and 4 in X-axis direction, and detection portions 7A, 7B, 8A, and 8B as displacement detecting means for detecting displacement of the vibrating bodies 3 and 4 in Y-axis direction.

Here, the element substrate 2 is formed by using a glass substrate, etc., for example. Furthermore, the vibrating bodies 3 and 4, drive portions 5A, 5B, 6A, and 6B, and detection portions 7A, 7B, 8A, and 8B are formed in such a way that fine processing such as etching, etc., is performed to a silicon substrate anodic bonded on the element substrate 2, for example. Furthermore, the vibrating bodies 3 and 4 are supported so as to be displaced in the X-axis direction and Y-axis direction by

using beams (not illustrated), and the drive portions 5A, 5B, 6A, and 6B and the detection portions 7A, 7B, 8A, and 8B are constituted by using comb-shaped electrodes, for example.

Moreover, as shown in Figs. 2 to 4, element-side drive electrodes 9 to 12, element-side detection electrodes 13 and 14, and ground electrodes as element-side low-impedance electrodes are contained on the back surface (mounting surface) of the element substrate 2. Then, the drive portions 5A, 5B, 6A, 6B are connected to the element-side drive electrodes 9, 10, 11, and 12 by using through-holes, etc., respectively, and the detection portions 7B and 8A are connected to the element-side detection electrode 14. Furthermore. The ground electrode 15 is connected to a ground electrode 35 on the side of a multilayer substrate 21 to be described later. Thus, the ground electrode 15 is held at a ground potential as a low-impedance reference potential, and the vibrating bodies 3 and 4 are connected to the ground electrode 15.

In this way, when drive signals  $Vd1$  and  $Vd2$  of voltages of opposite phase to each other, etc., are applied to the drive portions 5A and 5B, electrostatic attraction acts between the vibrating body 3 and the drive portions 5A and 5B in accordance with the drive signals  $Vd1$  and  $Vd2$  and the vibrating body 3 is vibrated in the X-axis direction. Then, when an angular velocity  $\Omega$  in the Z-axis direction perpendicular to the element substrate

2 is applied to the element substrate 2 in this state, a Coriolis force acts on the vibrating body 3 and the vibrating body 3 is displaced (vibrated) in the Y-axis direction. At this time, since the electrostatic capacitance between the detection portions 7A and 7B and the vibrating body 3 changes, the detection portions 7A and 7B output a voltage, etc., in accordance with the electrostatic capacitance as detection signals Vs1 and Vs2.

In the same way, drive signals Vd2 and Vd1 of opposite phase to each other are also applied to the drive portions 6A and 6B, when an angular velocity  $\Omega$  in the Z-axis direction is applied to the vibrating body 4, the vibrating body 4 is displaced (vibrated) in the Y-axis direction. Accordingly, the detection portions 8A and 8B output a voltage, etc., in accordance with the electrostatic capacitance between the detection portions 8A and 8B and the vibrating body 4 as detection signals Vs3 and Vs4.

Moreover, since the drive signal Vd1 is inputted to the drive portions 5A and 5B and the drive signal Vd2 is inputted to the drive portions 5B and 5A, the vibrating bodies 3 and 4 are vibrated in opposite direction to each other in the X-axis direction. Furthermore, since the vibrating bodies 3 and 4 are formed substantially in the same way, when the same angular velocity  $\Omega$  acts on the vibrating bodies 3 and 4, the amount of change of the detection signals Vs1 and Vs4 of the detection

portions 7A and 7B becomes the same and the amount of change of the detection signals Vs2 and Vs3 of the detection portions 7B and 7A also becomes the same. On the other hand, when the same acceleration in the Y-axis direction acts on the vibrating bodies 3 and 4, the amount of change of the detection signals Vs1 and Vs4 of the detection portions 7A and 7B becomes the same value of opposite sign to each other, and the amount of change of the detection signals Vs2 and Vs3 of the detection portions 7B and 7A also becomes the same value of opposite sign to each other. Accordingly, when the detection portions 7A and 7B are connected to the element-side detection electrode 13 and the detection portions 7B and 8A are connected to the element-side detection electrode 14, the acceleration components are removed from the detection signals Vs1 to Vs4 and only the acceleration components are outputted.

Here, the element-side drive electrodes 9 to 12 and element-side detection electrodes 13 and 14 are formed so as to be island-shaped. Furthermore, as shown in Figs. 3 and 4, the element-side drive electrodes 9 and 10 and the element-side drive electrodes 11 and 12 are positioned on the back surface (side) of the element substrate 2 and contained so as to be separated from each other in the Y-axis direction. On the other hand, the element-side detection electrodes 13 and 14 are disposed in the central portion () of the element substrate 2. Furthermore, the

ground electrode 15 is formed in a portion excluding the surrounding (vicinity) of the electrodes 9 to 14 on the back surface of the element substrate 2 so as to be insulated from the element-side drive electrodes 9 to 12 and the element-side detection electrodes 13 and 14. Accordingly, the ground electrode 15 is formed on the whole area of the back surface of the element substrate 2. However, in the ground electrode 15, an opening 16 is formed at the position of each of the element-side drive electrodes 9 and 10 and the element-side drive electrodes 11 and 12 and an opening 17 is formed at the position of the element-side detection electrodes 13 and 14. Thus, a frame-shaped frame portion 18 positioned around the opening 17 of the ground electrode 15 is disposed between the element-side detection electrodes 13 and 14 and the element-side drive electrodes 9 to 12 so as to include the element-side detection electrodes 13 and 14.

Then, the electrodes 9 to 15 are connected to electrodes 29 to 35 on the side of a multilayer substrate 21 to be described later.

Reference numeral 21 represents a multilayer substrate in which the angular velocity detection element 1, etc., are mounted. As shown in Figs. 7 to 9, the multilayer substrate 21 is constituted by three-layer insulation layers 22 to 24 made of ceramic material of alumina, etc., for example, and these



insulation layers 22 to 24 are laminated to each other. Then, a first electrode layer 25 on the surface 21A of the multilayer 21, a second electrode layer 26 is formed between the insulation layers 22 and 23, a third electrode layer 27 is formed between the insulation layers 23 and 24, and a fourth electrode layer 28 is formed on the back surface 21B of the multilayer substrate 21.

Reference numerals 29 to 32 represent belt-shaped substrate-side drive electrodes. The substrate-side drive electrodes 29 to 32 are disposed at locations facing the element-side drive electrodes 9 to 12 and extended from the central portion of the multilayer substrate 21 to the outer periphery portion. Then, the substrate-side drive electrodes 29 and 30 and the substrate-side drive electrodes 31 and 32 are disposed so as to be separated from each other in the Y-axis direction, the substrate-side drive electrodes 29 and 32 are connected to a drive wiring 41 to be described later, and the substrate-side drive electrodes 30 and 31 are connected to a drive wiring 42 to be described later.

Reference numerals 33 and 34 represent island-shaped substrate-side detection electrodes contained on the surface 21A of the multilayer substrate 21. The substrate-side detection electrodes 33 and 34 are disposed at locations facing the element-side detection electrodes 13 and 14 and positioned between the substrate-side drive electrodes 29 and 30 and the

substrate-side electrodes 31 and 32. Then, the substrate-side detection electrodes 33 and 34 are connected to detection wirings 43 and 44 contained inside the multilayer substrate 21 via through holes 46 and 47 to be described later.

Reference numeral 35 represents a ground electrode as a substrate-side low-impedance electrode contained on the surface 21A of the multilayer substrate 21. The ground electrode 35 is formed in the whole area facing the angular velocity detection element 1 on the surface 21A of the multilayer 21. However, the ground electrode 35 is formed in a portion excluding the periphery (vicinity) of the electrodes 29 to 34 so as to be isolated from the substrate-side drive electrodes 29 to 32 and the substrate-side detection electrodes 33 and 34. Accordingly, in the ground electrode 35, notches 36 extending along the electrodes 29 to 32 are formed at positions of the substrate-side drive electrodes 29 to 32 extending toward the outside of the multilayer substrate 21, and an opening 37 is formed at the position of the substrate-side detection electrodes 33 and 34. Thus, a frame-shaped frame portion 38 positioned around an opening 37 of the ground electrode 35 is disposed between the substrate-side detection electrodes 33 and 34 and the substrate-side drive electrodes 29 to 32 so as to enclose the substrate-side detection electrodes 33 and 34.

Furthermore, when the angular velocity detection element 1

is flip-chip mounted on the multilayer substrate 21, the ground electrode 35 on the side of the multilayer substrate 21 and the ground electrode 15 on the side of the angular velocity detection element 1 lie one on top of another (face each other) and the opposite portions A11 and A12 (portions enclosed by a broken line in Fig. 6) of the ground electrodes 15 and 35 are formed. At this time, the opposite portion A11 of the ground electrodes 15 and 35 is formed in the shape of a frame so as to enclose the element-side detection electrodes 13 and 14 and also enclose the substrate-side detection electrodes 33 and 34. Thus, the opposite portion A11 of the ground electrodes 15 and 35 is disposed between the element-side drive electrodes 9 to 12 and the element-side electrodes 13 and 14.

Furthermore, the opposite portion A12 of the ground electrodes 15 and 35 are formed so as to be disposed on both sides in the Y-axis direction of the facing-each-other portion A11 and to extend in the X-axis direction. Then, the element-side detection electrodes 33 and 34 are sandwiched between the facing-each-other portion A12 and the opposite portion A11 of the ground electrodes 15 and 35.

Furthermore, the ground electrode 35 is connected to a ground wiring 39 extending for a signal processing circuit portion 52 to be described later. Thus, the ground electrode 35 is connected to the ground electrode (not illustrated) of the

signal processing circuit portion 52 and kept at a ground potential as a low-impedance reference potential.

Moreover, a resist film 40 is contained substantially all over the surface of the multilayer substrate 21. Then, the resist film 40 covers the electrodes 29 to 35. However, the electrode pads 29A to 35A of the electrodes 29 to 35 are exposed. In this way, the electrodes 29 to 35 are connected to the electrode pads 9A to 15A of the angular velocity detection element 1 by using metal bumps B made of a conductive metal material such as gold, etc., for example, contained on the electrode pads 29A to 35A, and the angular velocity detection element 1 is flip-chip mounted on the multilayer substrate 21.

Reference numerals 41 and 42 represent drive wirings contained on the surface 21a of the multilayer substrate 21. As shown in Figs. 1 to 9, the drive wirings 41 and 42 are extended in the Y-axis direction of the multilayer substrate 21, connect the substrate-side drive electrodes 29 to 32 and the signal processing circuit portion 52, and constitute the first electrode layer 25 together with the electrodes 29 to 35 and the ground wiring 39. Here, the drive wiring 41 is connected to the substrate-side drive electrodes 29 to 32. On the other hand, the drive wiring 42 is positioned on the opposite side from the drive wiring 41 so as to sandwich the ground wiring 39, and connected to the substrate-side drive electrodes 30 and 31. In this way,

the drive wirings 41 and 42 supply the drive signals Vd1 and Vd2 of opposite phase to each other to be applied from the signal processing circuit portion 52 to the substrate-side drive electrodes 29 to 32, and make the vibrating bodies 3 and 4 vibrated in the X-axis direction.

Reference numerals 43 and 44 represent detection wirings contained inside the multilayer substrate 21. The detection wirings 43 and 44 are positioned between the insulation layers 23 and 24, and extended in parallel to each other and in the Y-axis direction so as to extend from the angular velocity detection element 1 to the signal processing circuit portion 52. Furthermore, a ground electrode 45 as a low-impedance wiring is contained between the insulation layers 23 and 24 so as to enclose each of the detection wirings 43 and 44. Here, the ground electrode 45 is connected to the ground electrode (not illustrated) of the signal processing circuit portion 52 via through-holes (not illustrated), etc. Then, the detection wirings 43 and 44 constitute the third electrode layer 27 together with the ground electrode 45.

Furthermore, in the detection wirings 43 and 44, one terminal is connected to the substrate-side detection electrodes 33 and 34 via through-holes 46 and 47 and the other terminal is connected to the signal processing circuit portion 52 via through-holes 48 and 49.

Reference numeral 50 represents a ground electrode as a low-impedance wiring contained between the insulation layers 22 and 23. The ground electrode 50 faces substantially the whole length of the detection wirings 43 and 44 and covers substantially the whole area on the surface side of the insulation layer 23. However, the ground electrode 50 is formed in the area where the surrounding of the through-holes 46 to 49 is excluded so that the ground electrode 50 may be insulated from the detection wirings 43 and 44, etc. Furthermore, the ground electrode 50 is connected to the ground electrode (not illustrated) of the signal processing circuit portion 52 and constitutes the second electrode layer 26. Then, the ground electrode 50 is disposed between the drive wirings 41 and 42 and the detection wirings 43 and 44 and makes the coupling capacitance between them reduced.

Reference numeral 51 represents a ground electrode as a low-impedance wiring contained on the back surface 21B of the multilayer substrate 21. The ground electrode 51 faces substantially the whole length of the detection wirings 43 and 44 and covers substantially the whole area of the back surface 21B. The ground electrode 51 is connected to the ground electrode (not illustrated) of the signal processing circuit portion 52 via through-holes (not illustrated), etc., and constitutes the fourth electrode layer 28. Then, the ground electrode 50 makes the coupling capacitance between the drive wirings 41 and 42 and the

detection wirings 41 and 42 and the detection wirings 43 and 44 reduced and prevents noise (noise signal) from the outside from mixing into the detection wirings 43 and 44.

Reference numeral 52 represents a signal processing circuit portion as a signal processing means contained on the surface 21A of the multilayer substrate 21. The signal processing circuit portion 52 is constituted by using a bare chip IC52A, a circuit part 52B, made up of various active elements and passive elements, etc., and the bare chip IC52A is flip-chip mounted, for example, and the circuit part 52B is SMD mounted (surface mounted) by using a reflow soldering process.

Furthermore, the signal processing circuit portion 52 is connected to the drive wirings 41 and 42, the detection wirings 43 and 44, the ground wiring 39, and the ground electrodes 45, 50, and 51, and also connected to a ground wiring 53, a power supply wiring 54, and an output signal wiring 55. Then, the signal processing circuit portion 52 is connected to the external ground via the ground wiring 53, and also a drive power supply voltage is supplied to the signal processing circuit portion 52 via the ground wiring 53. In this way, the signal processing circuit portion 52 supplies drive signals  $V_{d1}$  and  $V_{d2}$  in opposite phase to each other to the angular velocity detection element 1 through the drive wirings 41 and 42, and simultaneously receives detection signals  $V_{s1}$  to  $V_{s4}$  from the angular velocity detection

element 1 through the detection wirings 43 and 44 and outputs an output signal Vo in accordance with an angular velocity  $\Omega$  by performing various computations, etc. Furthermore, the signal processing circuit portion 52 outputs the output signal Vo to the outside through the output signal wiring 55.

The angular velocity measuring device according to the present embodiment has the above-described structure. Next, the operation is described.

First, when the signal output circuit portion 52 outputs drive signals in opposite phase to each other to the drive wirings 41 and 42, the drive signals Vd1 and Vd2 are applied to the drive portions 5A, 5B, 6A, and 6B of the angular velocity detection element 1 through the drive electrodes 9 to 12, and 29 to 32. Thus, an electrostatic attraction acts on the vibrating bodies 3 and 4 and the vibrating bodies 3 and 4 are vibrated in the direction of arrows a1 and a2 in Fig. 2 along the X axis. When an angular velocity  $\Omega$  acts around the Z axis in this state, since a Coriolis force shown by Formula 1 acts on the vibrating bodies 3 and 4, the vibrating bodies 3 and 4 are displaced and vibrated in the direction of arrows b1 and b2 in Fig. 2 along the Y axis in accordance with an angular velocity  $\Omega$ .

Formula 1

$$F = 2 \times M \times \Omega \times v$$

Where



$M$  = mass of vibrating bodies 3 and 4

$\Omega$  = angular velocity around Z axis

$V$  = velocity in the direction of X axis of vibrating bodies 3 and 4

At this time, since the electrostatic capacitance between the detection portions 7A, 7B, 8A, and 8B and the vibrating bodies 3 and 4 changes in accordance with the displacement in the direction of the Y axis of the vibrating bodies 3 and 4, the detection portions 7A, 7B, 8A, and 8B output detection signals Vs1 to Vs4 in accordance with the capacitance change of these. When these detection signals Vs1 to Vs4 are synthesized in the detection electrodes 13 and 14, acceleration components are removed and the detection signals Vs1 to Vs4 are inputted to the signal processing circuit portion 52 through the detection electrodes 33 and 34 and the detection wirings 43 and 44. Accordingly, the signal processing circuit portion 52 performs signal processing of synchronous detection, etc., of detection signals Vs1 to Vs4 to detect an angular velocity  $\Omega$  and output an output signal Vo to the outside.

At the same time, the drive signals Vd1 and Vd2 and the detection signals Vs1 to Vs4 contain relatively low frequencies of tens kHz and the coupling capacitance between the drive wirings 41 and 42 and the detection wirings 43 and 44 is very small (about a few fF, for example). Accordingly, since

crosstalk between the drive signals  $V_{d1}$  and  $V_{d2}$  and the detection signals  $V_{s1}$  to  $V_{s4}$  is very small, the mixture of signals due to crosstalk is negligible except for the angular velocity measuring device. In the angular velocity detection element 1, since the displacement of the vibrating bodies 3 and 4 due to a Coriolis force is very small, the detection signals  $V_{s1}$  to  $V_{s4}$  have a small value in comparison with the drive signals  $V_{d1}$  and  $V_{d2}$ . Furthermore, since the phase of crosstalk and the phase of detection are equal to each other, the crosstalk cannot be eliminated by the detection. Accordingly, even when the drive signals  $V_{d1}$  and  $V_{d2}$  slightly mix with the detection signals  $V_{s1}$  to  $V_{s4}$ , detection of output at rest and offset temperature drift characteristics are worsened.

Then, in a related technology, although the drive wiring and the detection wiring are formed so as to be symmetrical between them in order to offset the crosstalk between the drive signal and the detection signal, in this case, the freedom of a lead-in and lead-out wire is limited, and also, when the angular velocity detection element is mounted on a substrate as it is displaced, the coupling capacitance between the drive wiring and the detection wiring changes, and then, there is a problem in that the crosstalk cannot be fully offset.

On the contrary, according to the present embodiment, since the detection wirings 43 and 44 are contained inside the

multilayer substrate 21 and the ground electrodes 50 and 51 for covering the detection wirings 43 and 44 are contained at a different position (location) from the detection wirings 43 and 44 in the thickness direction, the detection wirings 43 and 44 of a high impedance can be shielded by using the ground electrodes 50 and 51. Accordingly, the drive signals  $V_{d1}$  and  $V_{d2}$  can be prevented from mixing with the detection signals  $V_{s1}$  to  $V_{s4}$  between the drive wirings 41 and 42 and the detection wirings 43 and 44, and, as a result, it is able to prevent deviation of output at rest and improve offset temperature drift characteristics.

Furthermore, since the angular velocity detection element 1, etc., are mounted on the multilayer substrate 21, in comparison with the case where a substrate of a single layer is used as in the related technology, the restrictions of a lead-in and lead-out wiring can be eliminated in the drive wirings 41 and 42, the detection wirings 43 and 44, etc., and the freedom of disposition of the element 1, etc., can be increased. As a result, the mounting area for the wirings 41 to 44, etc., is reduced and the device can be made smaller as a whole.

Moreover, since the wirings 41 to 44, etc., can be freely set by using the multilayer substrate 21, for example, the drive wirings 41 and 42 and the detection wirings 43 and 44 are disposed so as to be symmetrical and the coupling capacitance

between the drive wiring 41 and the detection wiring 43 can be set so as to be substantially equal to the coupling capacitance between the drive wiring 42 and the detection wiring 44.

Accordingly, even when the drive wirings 41 and 42 and the detection wiring 43 are coupled therebetween, the crosstalk between a drive signal and a detection signal is offset and the detection sensitivity can be increased.

Furthermore, since the wirings 41 to 44 can be freely set by using the multilayer substrate 21, the electrodes 29 to 35 for connection to the angular velocity detection element 1 can be disposed at thigh density on the surface 21A of the multilayer substrate 21, and also the substrate-side drive electrodes 29 to 32 and the substrate-side detection electrodes 33 and 34 can be disposed at free positions so as to face the element-side drive electrodes 9 to 12 and the element-side detection electrodes 13 and 14 on the surface 21A of the multilayer substrate 21.

Accordingly, the angular velocity detection element 1 can be flip-chip mounted on the multilayer substrate 21. As a result, in comparison with the case in which wire-bonding mounting is performed, productivity is improved, and simultaneously the mixture of noise from wires, etc., is removed and the detection sensitivity can be improved.

In particular, in the present embodiment, since the ground electrode 50 is disposed between the drive wirings 41 and 42 and

the detection wirings 43 and 44, the drive wirings 41 and 42 and the detection wirings 43 and 44 can be isolated from each other by using the ground electrode 50 and the occurrence of crosstalk between them can be surely prevented.

Furthermore, the element-side drive electrodes 9 to 12 and the element-side detection electrodes 13 and 14 are contained on the mounting surface of the angular velocity detection element 1, the substrate-side drive electrodes 29 to 32 and the substrate-side detection electrodes 33 and 34 are contained on the surface 21A of the multilayer substrate 21, the element-side drive electrodes 9 to 12 and the substrate-side drive electrodes 29 to 32 are connected, and the element-side detection electrodes 13 and 14 and the substrate-side detection electrodes 33 and 34 are connected, and thus, the angular velocity detection element 1 is flip-chip mounted on the multilayer substrate 21. Accordingly, for example, the bare chip IC52A, etc., constituting the signal processing circuit portion 52 are mounted and simultaneously the angular velocity detection element 1 can be mounted and, in comparison with the case where wire-bonding mounting is performed, the productivity can be improved.

Furthermore, since the ground electrode 15 positioned between the element-side drive electrodes 9 to 12 and the element-side detection electrodes 13 and 14 is contained on the mounting surface of the angular velocity detection element 1, the

coupling between the element-side drive electrodes 9 to 12 and the element-side detection electrodes 13 and 14 can be cut off from each other by the ground electrode 15. Furthermore, when the angular velocity detection element 1 is flip-chip mounted on the multilayer substrate 21, since the element-side drive electrodes 9 to 12 and the substrate-side drive electrodes 29 to 32 are connected so as to face each other and the element-side detection electrodes 13 and 14 and the substrate-side detection electrodes 33 and 34 are also connected so as to face each other, the ground electrode 15 is disposed between the substrate-side drive electrodes 29 to 32 and the substrate-side detection electrodes 33 and 34. Accordingly, the coupling between the substrate-side drive electrodes 29 to 32 and the substrate-side detection electrodes 33 and 34 is also cut off from each other by the ground electrode 15. As a result, the occurrence of crosstalk between the electrodes 29 to 32 and the electrodes 33 and 34 can be prevented and offset temperature drift characteristics, etc., can be improved.

Moreover, since the ground electrode 35 positioned between the substrate-side drive electrodes 29 to 32 and the substrate-side detection electrodes 33 and 34 is contained on the surface 21A of the multilayer substrate 21, the coupling between the substrate-side drive electrodes 29 to 32 and the substrate-side detection electrodes 33 and 34 can be cut off by the ground

electrode 35. Accordingly, due to the multiplication effect between the angular velocity detection element 1 and the ground electrode 15, the coupling between the drive electrodes 9 to 12 and 29 to 32 and the detection electrodes 13, 14, 33, and 34 can be surely cut off and the effect of cut-off of crosstalk can be increased.

Furthermore, in the related technology, when an angular velocity detection element is mounted on a substrate so as to be displaced, the coupling capacitance between the electrode pad on the substrate side and the electrode pad of the angular velocity detection element changes and there is a tendency that crosstalk occurs. However, in the present embodiment, since the ground electrodes 15 and 35 are contained between the drive electrodes 9 to 12, and 29 to 32 and the detection electrodes 13, 14, 33, and 34, even if the angular velocity detection element 1 is mounted on the multilayer substrate 21 so as to be displaced, the opposite portion A11 of the ground electrodes 15 and 35 can be disposed between the drive electrodes 9 to 12, and 29 to 32 and the detection electrodes 13, 14, 33, and 34. As a result, the coupling between the drive electrodes 9 to 12, and 29 to 32 and the detection electrodes 13, 14, 33, and 34 is cut off by using the opposite portion A11 of the ground electrodes 15 and 35 and the occurrence of crosstalk can be prevented.

Furthermore, since the angular velocity detection element 1

is flip-chip mounted on the multilayer substrate 21 by using metal bumps B, the substrate-side drive electrodes 29 to 32 and the element-side drive electrodes 9 to 12 are made very close to each other and, for example, both face each other with a gap of about tens  $\mu\text{m}$  therebetween. In the same way, the substrate-side detection electrodes 33 and 34 also face the element-side detection electrodes 13 and 14 so as to be close to each other. Accordingly, when the electrodes 9 to 14, and 29 to 34 are contained at high density, since the drive electrodes 9 to 12, and 29 to 32 become close to the detection electrodes 13, 14, 33, and 34, there is a tendency that crosstalk occurs between the substrate-side drive electrodes 29 to 32 and the element-side detection electrodes 13 and 14, and there is a tendency that crosstalk occurs also between the element-side drive electrodes 9 to 12 and the substrate-side detection electrodes 33 and 34.

However, in the present embodiment, when the angular velocity detection element 1 is flip-chip mounted on the multilayer substrate 21, the ground electrodes 15 and 35 partially face the element-side drive electrodes 9 to 12 and the element-side detection electrodes 13 and 14. At this time, the opposite portion A11 where the ground electrodes 15 and 35 face each other is positioned between the element-side drive electrodes 9 to 12 and the element-side detection electrodes 13 and 14 and also positioned between the substrate-side drive



electrodes 29 to 32 and the substrate-side detection electrodes 33 and 34. Accordingly, the coupling between the substrate-side electrodes 29 to 32 and the element-side detection electrodes 13 and 14 can be cut off by using the opposite portion A11 of the ground electrodes 15 and 35 and simultaneously the coupling between the electrode-side drive electrodes 9 to 12 and the substrate-side detection electrodes 33 and 34 can be also cut off. As a result, the occurrence of crosstalk between the electrodes 29 to 34 on the side of the multilayer substrate 21 and the electrodes 9 to 14 on the side of the angular velocity detection element 1 is prevented and offset temperature drift characteristics can be improved.

In particular, in the present embodiment, the opposite portion A11 of the ground electrodes 15 and 35 enclose the element-side detection electrodes 13 and 14 and also enclose the substrate-side detection electrodes 33 and 34. Accordingly, the coupling between the detection electrodes 13, 14, 33, and 35 and the element-side drive electrodes 9 to 12 and the substrate-side drive electrodes 29 to 32 can be surely cut off. As a result, the occurrence of crosstalk between the drive electrodes 9 to 12, and 29 to 33 and the detection electrodes 13, 14, 33, and 34 can be surely prevented.

Moreover, since the drive electrodes 9 to 12, and 29 to 32 are sandwiched between the opposite portions A11 and A12 of the

ground electrodes 15 and 35, the drive signals Vd1 and Vd2 can be surely enclosed around the drive electrodes 9 to 12, and 29 to 32 and the effect of suppressing crosstalk can be increased.

Furthermore, the through-holes 46 and 47 positioned at a portion where the angular velocity detection element 1 is mounted and for connecting the substrate-side detection electrodes 33 and 34 and the detection wirings 43 and 44 are contained in the multilayer substrate 21. Accordingly, the substrate-side electrodes 33 and 34 may be disposed at a position facing the element-side detection electrodes 13 and 14 of the angular velocity detection element 1, and the freedom of setting the other electrodes of the substrate-side drive electrodes 29 to 32, etc., can be increased. Furthermore, since the substrate-side detection electrodes 33 and 34 are connected to the detection wirings 43 and 44 contained inside the multilayer substrate 21 at a position where the angular velocity detection element 1 is mounted, in comparison with the case where the connection to the signal processing circuit portion 52 is performed on the side of the surface 21A of the multilayer substrate 21, the mixing of noise from the outside is prevented and the detection sensitivity of the angular velocity  $\Omega$  can be increased.

Furthermore, since the length dimension of the substrate-side detection electrodes 33 and 34 (the length dimension between the detection portions 7A, 7B, 8A, and 8B and the detection

wirings 43 and 44) can be shortened, the coupling of the substrate-side detection electrodes 33 and 34, etc., to the drive electrodes 29 to 32, etc., can be suppressed.

Moreover, since the vibrating bodies 3 and 4 of the angular velocity detection element 1, drive portions 5A, 5B, 6A, and 6B and detection portions 7A, 7B, 8A, and 8B are formed by fine processing of a silicon material, the angular velocity detection element 1 can be made smaller. Furthermore, since the detection wirings 43 and 44 are contained inside the multilayer substrate 21 and the freedom of arrangement of electrodes on the side of the multilayer substrate 21 is high, even if the electrodes 9 to 15 for external connection of the angular velocity detection element 1 are disposed at high density for size reduction, the angular velocity detection element 1 can be flip-chip mounted on the multilayer substrate 21.

Furthermore, since the detection portions 7A, 7B, 8A, and 8B of the angular velocity detection portion 1 is made to detect the electrostatic capacitance in accordance with the displacement of the vibrating bodies 3 and 4, there is a tendency that the detection signals  $V_{s1}$  to  $V_{s4}$  are likely to be deteriorate in accordance with the coupling capacitance between the detection wirings 43 and 44 and the drive wirings 41 and 42. On the contrary, in the present embodiment, since the detection wirings 43 and 44 are disposed inside the multilayer substrate 21 and the

detection wirings 43 and 44 are covered by the ground electrodes 45, 50, and 51, the coupling capacitance between the detection wirings 43 and 44 and the drive wirings 41 and 42 is reduced and the occurrence of crosstalk can be suppressed.

Moreover, since the insulation layers 22 to 24 of the multilayer substrate 21 are formed by using insulating ceramic material of alumina, for example, in the case where a glass substrate, etc., are used as the element substrate 2 of the angular velocity detection element 1, in comparison with the case where a resin material is used for the insulation layers 22 to 24, the difference of thermal expansion coefficients can be made smaller and the change of the detection sensitivity and output at rest can be suppressed.

Next, Fig. 10 shows a second embodiment of the present invention, and the present embodiment is characterized in that a bare chip IC to be flip-chip mounted out of circuit parts, etc., are contained on the surface side, in which an angular velocity detection element is contained, of a multilayer substrate and that the circuit parts to be surface mounted are contained on the back surface side of the multilayer substrate. Moreover, in the present embodiment, the same reference numeral is give the same component as in the first embodiment and its description is omitted.

Reference numeral 61 represents a signal processing circuit

portion as a signal processing means contained on the surface 21A of the multilayer substrate 21. The signal processing circuit portion 61 is constituted by a bare chip IC 61A, a circuit part 61B, etc., in the same way as in the first embodiment. Then, the bare chip IC 61A is positioned on the side of the surface 21A of the multilayer substrate 21 in the same way as the angular velocity detection element 1 and flip-chip mounted, and the circuit part 61B is positioned on the side of the back surface 21B of the multilayer substrate 21 different from the angular velocity detection element 1 and SMD mounted (surface mounted) by solder reflowing. Furthermore, the signal processing circuit portion 61 is connected to the drive wirings, detection wirings, (any one of them is not shown), etc.

Thus, also in the present embodiment constituted in this way, substantially the same operation-effect as in the first embodiment can be obtained. Then, in the present embodiment in particular, since the bare chip IC 61A which is to be flip-chip mounted in the signal processing circuit portion 11 is contained on the surface 21A of the multilayer substrate 21 in the same way as the angular velocity detection element 1, the bare chip IC 61A and the angular velocity detection element 1 can be mounted together on the multilayer substrate 21 and the productivity can be improved. Furthermore, since the circuit part 61B to be surface mounted is contained on the side of the back surface 21B

of the multilayer substrate 21 different from the angular velocity detection element 1, etc., when the circuit part 61B is reflow-soldered, it is able to prevent the mounting surface (electrodes, pads, etc.) of the angular velocity detection element 1, bare chip IC 61A, etc., from being contaminated. As a result, it is able to prevent defective joining, etc., in the flip-chip mounting and to improve the yield and reliability in the mounting.

Next, Figs. 11 to 15 show a third embodiment of the present invention and the present embodiment is characterized in that drive wirings are disposed inside a multilayer substrate and that substrate-side drive electrodes and substrate-side detection electrodes are enclosed by a ground electrode. Moreover, in the present embodiment, the same reference numeral is given the same component as in the first embodiment and its description is omitted.

Reference numerals 71 to 74 represent island-shaped element-side drive electrodes contained on the back surface (mounting surface) of an element substrate 2. The element-side drive electrodes 71 to 74 are connected to drive portions 5A, 5B, 6A, and 6B substantially in the same way as the element-side drive electrodes 9 to 12 according to the first embodiment. Thus, the element-side drive electrodes 71 to 74 input a drive signal Vd1 to the drive portions 5A and 5B and input a drive signal Vd2 to

the drive portions 5B and 6A.

Furthermore, as shown in Figs. 11 and 12, the element-side drive electrodes 71 and 72 and the element-side drive electrodes 73 and 74 are positioned on the back surface of the element substrate 2 and contained at positions separated in the direction of y axis.

Reference numerals 75 and 76 represent island-shaped element-side detection electrodes contained on the back surface of the element substrate 2. The element-side detection electrodes 75 and 76 are positioned between the element-side drive electrodes 73 and 74 and disposed on the side of the middle portion of the element substrate 2. Then, the element-side detection electrode 75 is connected to the detection portions 7A and 7B, and the element-side detection element 76 is connected to the detection portion 7B and 8A. Thus, the element-side detection electrodes 75 and 76 eliminate acceleration components from detection signals Vs1 to Vs4 outputted from the detection portions 7A, 7B, 8A, and 8B and output only angular velocity components.

Reference numeral 77 represents a ground electrode as an element-side low-impedance electrode contained on the back surface of the element substrate 2. The ground electrode 77 is formed in a portion which is the back surface of the element substrate 2 where the periphery (vicinity) of the electrodes 71

to 76 is removed so that the ground electrode 77 may be insulated from the element-side drive electrodes 71 to 74 and the element-side detection electrodes 75 and 76. Accordingly, the ground electrode 77 is formed all over the back surface of the element substrate 2. However, in the ground electrode 77, openings 78 are formed at the position of the element-side drive electrodes 71 and 72 and at the position of the element-side drive electrodes 73 and 74, and an opening 79 is formed at the position of the element-side detection electrodes 75 and 76. In this way, a frame-shaped frame portion 80 positioned around the opening 79 in the ground electrode 77 encloses the element-side detection electrodes 75 and 76, and is disposed between the element-side detection electrodes 75 and 76 and the element-side drive electrodes 71 to 74. Then, the ground electrode 77 is connected to a ground electrode 97 on the side of a multilayer substrate 81 to be described later and kept at a ground potential as a low-impedance reference potential.

Reference numeral 81 represents a multilayer substrate on which the angular velocity detection element 1, etc., are mounted. As shown in Fig. 15, the multilayer substrate 81 is constituted by four-layer insulation layers 82 to 85 made of a ceramic material such as alumina, etc., for example, and these insulation layers 82 to 85 are laminated. Then, a first electrode layer 86 is formed on the surface 81A of the multilayer substrate 81, a



second electrode layer 87 is formed between the insulation layers 82 and 83, a third electrode layer 88 is formed between insulation layers 83 and 84, a fourth electrode layer 89 is formed between the insulation layers 84 and 85, and a fifth electrode layer 90 is formed on the back surface of the multilayer substrate 81.

Reference numerals 91 to 94 represent substrate-side drive electrodes contained on the surface 81A of the multilayer substrate 81 (surface of the insulation layer 82 of the uppermost layer). As shown in Figs. 13 and 14, the substrate-side drive electrodes 91 to 94 are formed so as to be island-shaped and disposed at the positions facing the element-side drive electrodes 71 to 74. Then, the substrate-side drive electrodes 91 and 92 and the substrate-side drive electrodes 93 and 94 are disposed so as to be separated from each other in the direction of Y axis, and the substrate-side drive electrodes 91 and 94 are connected to a drive wiring 102 to be described later and the substrate-side drive electrodes 92 and 93 are connected a drive wiring 103 to be described later.

Reference numerals 95 and 96 represent substrate-side detection electrodes contained on the surface 81A of the multilayer substrate 81. The substrate-side detection electrodes 95 and 96 are disposed at the positions facing the element-side detection electrodes 75 and 76 and positioned between the

substrate-side drive electrodes 91 and 92 and the substrate-side drive electrodes 93 and 94. Then, the substrate-side detection electrodes 95 and 96 are connected to detection wirings 105 and 106 contained inside the multilayer substrate 81 via through-holes 108 and 109 to be described later.

Reference numeral 97 represents a ground electrode as a substrate-side low-impedance electrode contained on the surface 81A of the multilayer substrate 81. The ground electrode 97 is formed all over the portion facing the angular velocity detection element 1 on the surface 81A of the multilayer substrate 81. However, the ground electrode 97 is formed in a portion where the periphery (vicinity) of the electrodes 91 to 96 is removed so that the ground electrode 97 may be insulated from the substrate-side drive electrodes 91 to 94 and the substrate-side detection electrodes 95 and 96. Accordingly, in the ground electrode 97, openings 98 are formed at the position of the substrate-side drive electrodes 91 to 94, and openings 99 are formed at the position of the substrate-side detection electrodes 95 and 96. Thus, in the ground electrode 97, a frame-shaped frame portion 100 positioned around the openings 99 encloses the substrate-side detection electrodes 95 and 96 and is disposed between the substrate-side detection electrodes 95 and 96 and the substrate-side drive electrodes 91 to 94. Then, the ground electrode 97 constitutes a first electrode layer 86 to be described later

together with the substrate-side drive electrodes 91 to 94, the substrate-side detection electrodes 95 and 96, etc.

Furthermore, when the angular velocity detection element 1 is flip-chip mounted on the multilayer substrate 81, the ground electrode 97 on the side of the multilayer substrate 81 faces the ground electrode 77 on the side of the angular velocity detection element 1 (both ground electrodes 97 and 77 lie one on top of another), and the opposite portion A31 of the ground electrodes 77 and 97 is formed (portion enclosed by a broken line in Fig. 14). At this time, the opposite portion A31 of the ground electrodes 77 and 97 contain three openings A31a, A31b, and A31c. Then, the detection electrodes 75, 76, 95, and 96 are disposed inside the opening A31a, the drive electrodes 71, 72, 91, and 92 are disposed inside the opening A31b, and the drive electrodes 73, 74, 93, and 94 are disposed inside the opening A31c. Accordingly, the opposite portion A31 of the ground electrodes 77 and 97 enclose the element-side detection electrodes 75 and 76 and the substrate-side detection electrodes 95 and 96 and the substrate-side drive electrodes 71 and 72 and the substrate-side drive electrodes 91 and 92, and enclose the element-side drive electrodes 73 and 74 and the substrate-side drive electrodes 93 and 94. In this way, the opposite portion A31 of the ground electrodes 77 and 97 is disposed between the element-side

electrodes 71 to 74 and the element-side detection electrodes 75 and 76.

Furthermore, the ground electrode 97 is connected to a ground electrode 104, to be described later, contained inside the multilayer substrate 81 via a through-hole. Furthermore, the ground electrode 104 is connected to the signal processing circuit portion 52 via a through-hole. Accordingly, the ground electrode 97 is connected to the ground electrode (not illustrated) of the signal processing circuit portion 52 and kept at ground potential as a reference potential of a low-impedance.

Moreover, a resist film 101 is contained substantially all over the surface of the multilayer substrate 81. Then, the resist film 101 covers the electrodes 91 to 97. However, in the electrodes 91 to 97, electrode pads 91A to 97A are exposed. Thus, the electrodes 91 to 97 are connected to the electrodes 71 to 77 by using metal bumps B made of a conductive metal material such as gold, etc., for example, contained on the electrode pads 91A to 97A, and the angular velocity detection element 1 is flip-chip mounted on the multilayer substrate 81.

Reference numerals 102 and 103 represent drive wirings contained between the insulation layers 82 and 83. As shown in Fig. 15, the drive wirings 102 and 103 extend in the direction of Y axis of the multilayer substrate 81 and connect the substrate-side drive electrodes 91 to 94 and the signal processing circuit

portion 52. Furthermore, the drive wirings 102 and 103 are formed so as to be symmetrical in the direction of X axis. Here, the drive wiring 102 is connected to the substrate-side drive electrodes 91 and 94, and the drive wiring 103 is connected to the substrate-side drive electrodes 92 and 93. In this way, the drive wirings 102 and 103 supply the drive signals Vd1 and Vd2 in opposition phase to each other applied from the signal processing circuit portion 52 to the substrate-side drive electrodes 91 to 94, and make the vibrating bodies 3 and 4 of the angular velocity detection element 1 vibrate in the direction of X axis.

Reference numeral 104 represents a ground electrode contained between the insulation layers 82 and 83. The ground electrode 104 encloses each of the drive wirings 102 and 103. Here, one terminal side of the ground electrode 104 is connected to the ground electrode 97 of the multilayer substrate 81 via a through-hole (not illustrated) and the other terminal side is connected to the ground electrode (not illustrated) of the signal processing circuit portion 52 via a through-hole (not illustrated). Then, the ground electrode 104 constitutes a second electrode layer 87 together with the drive wirings 102 and 103.

Reference numerals 105 and 106 represent detection wirings contained inside the multilayer substrate 81. The detection wirings 105 and 106 are positioned between the insulation layers

84 and 85, and extended in the direction of Y axis in parallel to each other toward the signal processing circuit portion 52 from the angular velocity detection element 1. Furthermore, a ground electrode 107 as a low-impedance wiring enclosing each of the detection wirings 105 and 106 are contained between the insulation layers 84 and 85. Here, the ground electrode 107 is connected to the ground electrode (not illustrated) of the signal processing circuit portion 52 via a through-hole (not illustrated), etc. Then, the detection wirings 105 and 106 constitute a fourth electrode layer 89 together with the ground electrode 107.

Furthermore, one terminal side of the detection wirings 105 and 106 is connected to the substrate-side detection electrodes 95 and 96 via through-holes 108 and 109, and the other terminal side is connected to the signal processing circuit portion 52 via through-holes 110 and 111.

Reference numeral 112 represents a ground electrode as a low-impedance wiring contained between the insulation layers 83 and 84. the ground electrode 112 faces substantially the whole length of the detection wirings 105 and 106 and covers substantially all of the surface of the insulation layer 84. However, the ground electrode 112 is formed at a position where the periphery of the through-holes 108 to 111 is excluded so that the ground electrode 112 may be insulated from the detection

wirings 105 and 106, etc. Furthermore, the ground electrode 112 is connected to the ground electrode (not illustrated) of the signal processing circuit portion 52 via a through-hole (not illustrated), etc., and constitutes a third electrode layer 88. Then, the ground electrode 112 is disposed between the drive wirings 102 and 103 and the detection wirings 105 and 106 and makes a coupling capacitance between these smaller.

Reference numeral 113 represents a ground electrode as a low-impedance wiring contained on the back surface 81B of the multilayer substrate 81. The ground electrode 113 faces substantially all the length of the detection wirings 105 and 106 and covers substantially all of the back surface 81B. Furthermore, the ground electrode 113 is connected to the ground electrode (not illustrated) of the signal processing circuit portion 52 via a through-hole (not illustrated), etc., and constitutes a fifth electrode layer 90. Then, the ground electrode 113 makes the coupling capacitance between the drive wirings 102 and 103 and the detection wirings 105 and 106 smaller and prevents noise (noise signals) from the outside from mixing into the detection wirings 105 and 106.

Thus, also in the present embodiment constituted in this way, substantially the same operation-effect as in the first embodiment can be obtained. In particular, in the present embodiment, the drive wirings 102 and 103 are disposed inside the

multilayer substrate 81, and the substrate-side drive electrodes 91 to 94 and the substrate-side detection electrodes 95 and 96 are enclosed by using the ground electrode 97. At this time, element-side drive electrodes 71 to 74 and the element-side detection electrodes 75 and 76 each are also enclosed by the ground electrode 77. Accordingly, the opposite portion A31 of the ground electrodes 77 and 97 encloses the element-side detection electrodes 75 and 76 and the substrate-side detection electrodes 95 and 96 and can enclose the element-side drive electrodes 71 to 74 and the substrate-side drive electrodes 91 to 94. In this way, the opposite position A31 of the ground electrodes 77 and 97 cuts off the coupling between the drive electrodes 71 to 74, and 91 to 94 the detection electrodes 75, 76, 95, and 96, and it is able to surely prevent the occurrence of crosstalk.

Furthermore, since the opposite portion A31 of the ground electrodes 77 and 97 encloses the drive electrodes 71 to 74, and 91 to 97, it is able to prevent crosstalk between the drive electrodes 71 to 74, and 91 to 94 and not only the detection electrodes 75, 76, 95, and 96, but also the other electrodes. Accordingly, when a monitoring means (not illustrated) for detecting the vibration in the direction of vibration (direction of x axis) of the vibrating bodies 3 and 4 is contained in the angular velocity detection element 1, as shown by a two-dot line



in Figs. 11 and 12, for example, monitoring electrodes 114 and 115 connected to the monitoring means can be contained outside the ground electrodes 77 and 97. At this time, the monitoring means is constituted by comb-shaped electrodes in the same way as a displacement detecting means and the same monitoring signals as the detection signals Vs1 to Vs4 can be outputted. Accordingly, the monitoring signals are also easily affected by the drive signals Vd1 and Vd2. On the contrary, in the present embodiment, since the opposite portion A31 of the ground electrodes 77 and 97 encloses the drive electrodes 71 to 74, and 91 to 94, the coupling between the drive electrodes 71 to 74, and 91 to 94 and the monitoring electrodes 114 and 115 is cut off, and the detection accuracy of monitoring signals can be increased.

Moreover, in the third embodiment, the opposite portion A31 of the ground electrodes 77 and 97 encloses the detection electrodes 75, 76, 95, and 96 without being disconnected all around them. However, the present invention is not limited to this, and, like a first modified example shown in Figs. 16 and 17, for example, when openings 98' of a ground electrode 97' on the side of the multilayer substrate 81 is made larger, a part of a portion including the detection electrodes 75, 76, 95, and 96 of an opposite portion A31' of the ground electrodes 77 and 97' may be disconnected. Also in the first modified example, since an opposite portion A32' where the ground electrodes 77 and 97' face

each other are formed between the dielectric electrodes 75, 76, 95, and 96 and the drive electrodes 71 to 74, and 91 to 94, the coupling between the detection electrodes 75, 76, 95, and 96 and the drive electrodes 71 to 74, and 91 to 94 can be cut off.

Next, Figs. 18 to 20 show a fourth embodiment of the present invention, and the present embodiment is characterized in that a ground electrode is contained between the element-side electrodes and the element-side detection electrodes, that a ground electrode is contained between the substrate-side drive electrodes and the substrate-side detection electrodes, and that the element-side ground electrode and the substrate-side electrode are made to at least partly face each other. Moreover, in the present embodiment, the same reference numeral is given the same component as in the first embodiment and its description is omitted.

Reference numerals 121 to 124 represent island-shaped element-side drive electrodes contained on the back surface (mounting surface) of the element substrate 2. The element-side drive electrodes 121 to 124 are connected to the drive portions 5A, 5B, 6A, and 6B substantially in the same way as the element-side drive electrodes 9 to 12 according to the first embodiment. In this way, the element-side drive electrodes 121 to 124 input a drive signal Vd1 to the drive portions 5A and 6B, and input a drive signal Vd2 to the drive portions 5B and 6A.

Furthermore, as shown in Figs. 18 and 20, the element-side drive electrodes 121 and 122 and the element-side drive electrodes 123 and 124 are positioned on the back surface side of the element substrate 2 and contained at positions separated from each other in the direction of Y axis.

Reference numerals 125 and 126 represent island-shaped element-side detection electrodes contained on the back surface of the element substrate 2. The element-side detection electrodes 125 and 126 are positioned between the element-side drive electrodes 121 and 122 and the element-side drive electrodes 123 and 124 and disposed on the side of the middle portion of the element substrate 2. Then, the element-side detection electrode 125 is connected to the detection portions 7A and 7B, and the element-side detection electrode 126 is connected to the detection portions 7B and 8A. Thus, the element-side detection electrodes 125 and 126 eliminate acceleration components from detection signals Vs1 to Vs4 outputted from the detection portions 7A, 7B, 8a, and 8B, and output only angular velocity components.

Reference numerals 127 represent ground electrodes as element-side low-impedance electrodes, two of which are contained on the back surface of the element substrate 2. Here, one ground electrode 127 is disposed between the element-side drive electrodes 121 and 122 and the element-side detection electrodes

125 and 126, and the other ground electrode 127 is disposed between the element-side drive electrodes 123 and 124 and the element-side detection electrodes 125 and 126. Then, these ground electrodes 127 are formed in a portion excluding the periphery (vicinity) of the electrodes 121 to 126 of the back surface of the element substrate 2 so that the ground electrode 127 may be insulated from the element-side drive electrodes 121 to 124 and the element-side detection electrodes 125 and 126. Furthermore, the ground electrodes 127 are connected to a ground electrode 135 on the side of the multilayer substrate 128 to be described later and kept at a ground potential as a low-impedance reference potential.

Reference numeral 128 represents a multilayer substrate where the angular velocity detection element 1, etc., are mounted. The multilayer substrate 128 is constituted by four-layer insulation layers 82 to 85 substantially in the same way as the multilayer substrate 81 according to the third embodiment, for example, and the ground electrode, etc., (not illustrated) as a drive wiring, detection wiring, and low-impedance wiring are contained.

Reference numerals 129 to 132 represent substrate-side drive electrodes contained on the surface 128a of the multilayer substrate 128. The substrate-side drive electrodes 129 to 132 are formed so as to be island-shaped as shown in figs. 19 and 20,

and disposed at positions facing the element-side drive electrodes 121 to 124. Furthermore, the substrate-side drive electrodes 129 and 1430 and the substrate-side drive electrodes 131 and 132 are disposed so as to be separated in the direction of Y axis, and the substrate-side drive electrodes 129 to 132 are connected to the drive wirings (not illustrated) inside the multilayer substrate 128, respectively. Then, a drive signal Vd1 is applied to the substrate-side drive electrodes 129 and 132, and a drive signal Vd2 is applied to the substrate-side drive electrodes 130 and 131.

Reference numerals 133 and 134 represent substrate-side detection electrodes contained on the surface 128a of the multilayer substrate 128. The substrate-side detection electrodes 133 and 134 are disposed at positions facing the element-side detection electrodes 125 and 126, and positioned between the substrate-side electrodes 129 and 130 and the substrate-side drive electrodes 131 and 132. Then, the substrate-side detection electrodes 133 and 134 are connected to the detection wiring (not illustrated) inside the multilayer substrate 81.

Reference numerals 135 represent ground electrodes as substrate-side low-impedance electrodes, two of which are contained on the surface 128a of the multilayer substrate 128. Here, one ground electrode 135 is disposed between the substrate-

side drive electrodes 129 and 130 and the substrate-side detection electrodes 133 and 134, and the other ground electrode 135 is disposed between the substrate-side drive electrodes 131 and 132 and the substrate-side detection electrodes 133 and 134. Then, these ground electrodes 135 are formed in a portion excluding the periphery (vicinity) of the electrodes 129 to 134 of the surface 128a of the multilayer substrate 128 so that the ground electrodes 135 may be insulated from the substrate-side drive electrodes 129 to 132 and the substrate-side detection electrodes 133 and 134.

Furthermore, the ground electrode 135 is connected to a ground electrode (not illustrated) contained inside the multilayer substrate 128 via a through-hole. Then, the ground electrode 135 is connected to the signal processing circuit portion via the ground electrode inside the multilayer substrate 128 and kept at a ground potential as a low-impedance reference potential.

Furthermore, when the angular velocity detection element 1 is flip-flop mounted on the multilayer substrate 128, the ground electrode 135 on the side of the multilayer substrate 128 faces the ground electrode 127 on the side of the angular velocity detection element 1 and the opposite portion A41 (portion enclosed by a broken line in Fig. 20) of the ground electrodes 127 and 135 is formed on both sides in the direction of Y axis of

he detection electrodes 125, 126, 133, and 134. At this time, one opposite portion A41 of the ground electrodes 127 and 135 is disposed between the drive electrodes 121, 122, 129, and 130 and the detection electrodes 125, 126 133, and 134. Furthermore, the other opposite portion A41 of the ground electrodes 127 and 135 is disposed between the drive electrodes 123, 124, 131, and 132 and the detection electrodes 125, 126, 133, and 134.

Then, the electrodes 129 to 135 are connected to the electrodes 121 to 127 of the angular velocity detection element 1 by using metal bumps B made of a conductive metal material such as gold, etc., for example, and the angular velocity detection element 1 is flip-chip mounted on the multilayer substrate 128.

Thus, also in the present embodiment constituted in this way, substantially the same operation-effect as in the first embodiment can be obtained. Inparticular, in the present embodiment, since the opposite portion A41 of the ground electrodes 127 and 135 is contained between the drive electrodes 121 to 124, and 129 to 132 and the detection electrodes 125, 126, 133, and 134, the coupling between the drive electrodes 121 to 124, and 129 to 132 and the detection electrodes 125, 126, 133, and 134 is cut off by using the opposite portion A41 of the ground electrodes 127 and 135, and the occurrence of crosstalk can be prevented.

Furthermore, in the present embodiment, the ground

electrodes 127 and 135 do not enclose the drive electrodes 121 to 124, 129 to 132 and the detection electrodes 125, 126, 133, and 134, and is contained only between the drive electrodes 121 to 124, and 129 to 132 and the detection electrodes 125, 126, 133, and 134. Accordingly, various windings can be disposed around the drive electrodes 121 to 124, and 129 to 132, for example, and the back surface of the element substrate 2 and the surface of the multilayer substrate 128 can be effectively used.

Moreover, in each above-described embodiment, an angular velocity detection element 1 made up of two vibrating bodies 3 and 4 is used. However, the present invention is not limited to this, and, in the same way as the related technology, an angular velocity detection element made up of a single vibrating body may be used.

Furthermore, in the above-described first and second embodiments, although the ground electrodes 50 and 51 are contained in the second and fourth electrode layers 26 and 28 so as to sandwich the detection wirings 43 and 44 constituting the third electrode layer 27, both of the two ground electrodes 50 and 51 are not necessarily required, and either of the two may be used. Also in the third embodiment, although the two ground electrodes 112 and 113 are contained, either ground electrode may be contained.

Furthermore, in each above-described embodiment, the



element-side drive electrodes 9 to 12, 71 to 74, and 121 to 124, the element-side detection electrodes 13, 14, 75, 76, 125, and 126, and the ground electrodes 15, 77, and 127 are formed so as to be symmetrical in the direction of X axis and the direction of Y axis around the center of these and the coupling capacitance between the element-side detection electrodes 13, 75, and 125 and the element-side drive electrodes 9 to 12, 71 to 74, and 121 to 124 is set so as to be substantially the same as the coupling capacitance between the element-side detection electrodes 14, 76, and 126 and the element-side drive electrodes 9 to 12, 71 to 74, and 121 to 124. However, the present invention is not limited to these, and when the ground electrodes 15, 77, and 127 are disposed between the element-side drive electrodes 9 to 12, 71 to 74, and 121 to 124 and the element-side detection electrodes 13, 14, 75, 76, 125, and 126, the above-described coupling capacitance may be different from each other.

In the same way, although the substrate-side drive electrodes 29 to 32, 91 to 94, and 129 to 132, the substrate-side detection electrodes 33, 34, 95, 96, 133, and 134, and the ground electrodes 35, 97, and 135 are formed so as to be symmetrical in the direction of X axis and the direction of Y axis around the center of these and the coupling capacitance between the substrate-side detection electrodes 33, 95, and 133 and the substrate-side drive electrodes 29 to 32, 91 to 94, and 129 to

132 is set so as to be substantially the same as the coupling capacitance between the substrate-side detection electrodes 34, 96, and 124 and the substrate-side drive electrodes 29 to 32, 91 to 94, and 129 to 132, when the ground electrodes 35, 97, and 135 are disposed between the substrate-side drive electrodes 29 to 32, 91 to 94, and 129 to 132 and the substrate-side detection electrodes 33, 34, 95, 96, 133, and 134, the above-described coupling capacitance may be different from each other.

Furthermore, in each above-described embodiment, the ground electrodes 15, 35, 77, 97, 127, and 135 as a low-impedance electrode are used, and the ground electrodes 45, 50, 51, 107, 112, and 113 as a low-impedance wiring are used. However, the present invention is not limited to these, the low-impedance electrode and low-impedance wiring are not necessarily connected to the ground, and a low-impedance DC voltage wiring may be used as a low-impedance wiring, for example.

Moreover, in the above-described first and second embodiments, a multilayer substrate 21 made up of three-layer insulation layers 22 to 24 (four-layer electrode layers 25 to 28) is used, and, in the third embodiment, a multilayer substrate 81 made up of four-layer insulation layers 82 to 85 (five-layer electrodes layers 86 to 90) is used. However, the present invention is not limited these, and a multilayer substrate made up of five or more insulation layers (six or more electrode

layers) may be used, for example.

Furthermore, in each above-described embodiment, although the insulation layers 22 to 24, and 82 to 85 are formed by using alumina (aluminum oxide), they may be formed by using other ceramic materials or other insulation materials of resin materials, etc.

Furthermore, in each above-described embodiment, the drive wirings 41, 42, 102, and 103 are disposed at different positions from the detection wirings 43, 44, 105, and 106 in the thickness direction of the multilayer substrates 21 and 81. However, the present invention is not limited to these, and, for example, the drive wiring may be contained at a position (other electrode layer) different from the detection wiring in the thickness direction of the multilayer substrate and may be disposed at the same position as the detection wiring in the thickness direction of the multilayer substrate.

In particular, when the drive wiring and the detection wiring are disposed at the same position in the thickness direction of the multilayer substrate, a low-impedance wiring is contained at a position different from the detection wiring, etc., in the thickness direction of the multilayer substrate and another low-impedance wiring may be contained at the same position as the detection wiring, etc., and between the drive wiring and the detection wiring. In this case, the drive wiring

and the detection wiring can be isolated from each other by using another low-impedance wiring and the occurrence of crosstalk between them can be surely prevented.

Moreover, in each above-described embodiment, the large-in-width ground electrodes 50, 51, 112, and 113 facing the detection wirings 43, 44, 105, and 106 are used. However, the present invention is not limited to these, and a small-in-width (long and narrow) ground electrode as a low-impedance wiring facing the detection wiring may be used. Furthermore, in each above-described embodiment, although the ground electrodes 50, 51, 112, and 114 as a low-impedance wiring faces the detection wirings 43, 44, 105, and 106 substantially all over the length, the low-impedance wiring is not necessarily required to face the detection wiring all over the length (overt the whole length), and, for example, the low-impedance wiring may face a part of the whole length of the detection wiring.